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(12) # EUROPEAN PATENT APPLICATION

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(54) **Training ammunition projectile.**

(57) An axisymmetrical projectile having a specified design launch condition includes an axisymmetrical cavity 12 substantially filled with liquid, the cavity dimensions and liquid characteristics being so tuned that a main natural frequency of the liquid within the cavity approaches a nutation frequency of the projectile to cause resonance after a predetermined duration of flight following a design launch. The resonance increases the nutation amplitude causing a rapid rise in drag which quickly halts the projectile's flight.

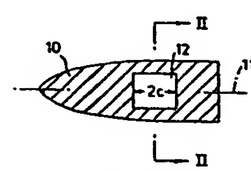

Fig.1.

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TRAINING AMMUNITION ROUNDS

The present invention relates to training ammunition rounds of the axisymmetrical type such as bullets and shells. Such a round will in this specification be referred to as a projectile.

Ammunition rounds, other than for small arms, usually contain explosive warheads and their use for training purposes is therefore inordinately expensive as well as unnecessarily dangerous. It is common, therefore, to produce projectiles specifically for training purposes.

A problem that arises in the use of training projectiles is that the target range is usually much less than the potential maximum projectile range. In realistic battle training, therefore, much greater areas must be used than are called for merely by expected target ranges.

There is, then, a requirement for training projectiles whose ballistic characteristics alter after travelling just beyond the target range so that that range is substantially the maximum range. Projectiles tried have been

1 A composite projectile having a nose which melts due to aerodynamic heating, so allowing the projectile to break up into several smaller pieces, and

2 A spinning tubular projectile which at high Mach numbers has "swallowed" internal flow but as the Mach number decreases the internal flow chokes with a consequent rise in drag.

These still leave problems in achieving the desired change in ballistic requirements whilst consistently maintaining a ballistic

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performance accurately representative of operational projectiles up to the full target range.

Almost all projectiles spin in flight, and with any spinning axisymmetric projectile the axis of symmetry performs angular oscillatory motions with respect to the tangent to the trajectory. These oscillatory motions have two natural frequencies, a slower precession frequency and a faster nutation frequency.

According to the present invention an axisymmetrical projectile having a specified design launch condition includes an axisymmetrical cavity substantially filled with liquid, the cavity dimensions and liquid characteristics being so tuned that a main natural frequency of the liquid within the cavity approaches a nutation frequency of the projectile to cause resonance after a predetermined duration of flight following a design launch.

Resonance results in the nutation amplitudes becoming undamped, giving a rapid increase in yaw angle and hence a sudden increase in drag which will rapidly terminate the projectile's flight. The predetermined duration of flight should be such that resonance occurs just after target range has been passed.

Some embodiments of the invention will now be described, by way of example, with reference to the accompanying diagrammatic drawings, of which

Figure 1 is a side elevation, in section, of a spin stabilised projectile.

Figure 2 is an end elevation in section along line II-II of Figure 1, and

Figure 3 is a side elevation of a fin stabilised projectile.

A projectile 10 (Figures 1 and 2) having an axis of symmetry 11 has within it an axisymmetrical cylindrical cavity 12 of length 2c and diameter 2a. The cavity 12 is substantially filled with a liquid. The liquid has a double

infinity of natural frequencies of which the frequency of the principal mode of oscillation τ_0 is well documented as a function of the liquid characteristics, the fineness ratio c/a, and the fraction of cavity 12 volume filled with liquid. Calibration tables are contained, for example, in the United States Arms Material Command Pamphlet 706165 "Liquid Filled Projectile Design".

In use the projectile 10 is launched from a fire-arm (not shown) at a velocity v and having a spin rate α imparted by rifling within the fire-arm. In flight the projectile oscillates with a nutation frequency τ_1 which is a function of spin rate α/velocity v. Both v and α decay due to air resistance during flight, but v decays at a faster rate than α so that τ_1 increases during flight.

It can be shown mathematically that resonance occurs between the liquid within cavity 12 and the nutation frequency τ_1, if

$$-1 < \frac{\tau_1 - \tau_0}{\sqrt{s}} < 1$$

where s is the Stewartson parameter. The Stewartson parameter is a function of the projectile dimensions and inertia, the cavity dimensions and the liquid physical properties, and is defined in the above referenced pamphlet.

If, on projection of the projectile, $\tau_1 < \tau_0 - \sqrt{s}$, $\dot{\tau}_1$ increases during flight, until $\tau_1 = \tau_0 - \sqrt{s}$. Any further increase of τ_1 results in resonance, which causes rapid divergence of the projectile yaw angle. The subsequent rapid increase in drag quickly terminates the flight of projectile 10.

Modern ballistic theory, projectile design, and production methods are such that launch velocity and spin rate, and velocity and spin decay rates, are maintained within very small tolerances of a projectile specified launch condition. Liquid within cavity 12 of a projectile 10 can therefore be tuned, by changing the fill fraction, the fineness ratio, or both, to ensure that

resonance occurs, after a specified launch, after a predetermined flight duration, and hence at a predetermined range, within very fine limits.

Another type of axisymmetrical projectile 13 (Figure 3) is stabilised by fins 14 which set up a slow spin-rate (relative to the spin rate of a spin stabilised projectile). Due to the effects of the fins 14 the velocity and spin rate decay at the same rates, so that the nutation frequency τ_1 remains substantially constant. In this type of projectile a cavity (not shown, but similar to that described above and illustrated in Figures 1 and 2) contains liquid which, relatively slowly, takes up the spin rate of the projectile 13. The liquid and cavity are tuned so that the liquid resonates with the equilibrium nutation frequency when the liquid has the same spin rate as the projectile 13, and so that the liquid reaches the spin rate of the projectile 13 after a predetermined flight duration.

It will be appreciated by those skilled in the art that variations in the above described projectiles are possible within the scope of the invention. For example the cavity 12 may be of axisymmetric spheroidal shape. When completely filled with liquid, the liquid has a single natural frequency of oscillation in such a cavity. Construction of a projectile with this shape of cavity is, however, complicated.

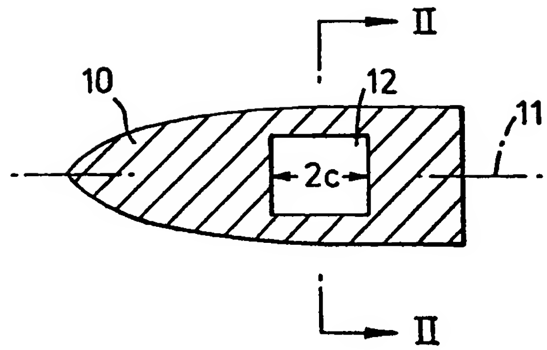

Fig. 1.

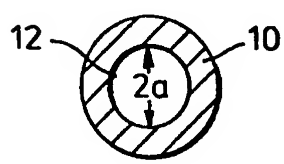

Fig. 2.

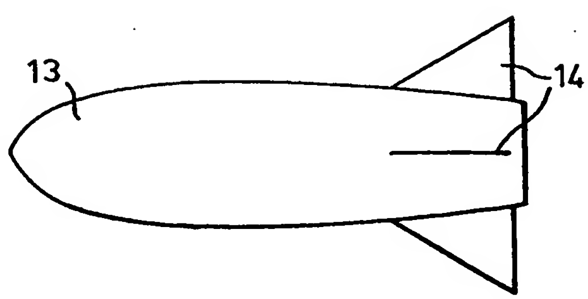

Fig. 3.